

## The International Energy Conservation Code

# Performance testing: a primer

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By Craig Drumheller  
Senior Energy Engineer, NAIHB Research Center

Energy efficiency requirements for new-home construction have been significantly increased with the introduction of the 2009 International Energy Conservation Code (IECC), and this updated code is becoming more and more pervasive in local jurisdictions around the country. It is likely that most new construction using the 2009 IECC will require some type of performance testing for ducts, as well as the whole building. In the past, building performance tests have been reserved strictly for high-performance, Energy Star-type homes.

What does this mean for builders? As with most updated codes, there are a number of specific changes throughout the latest version of the energy code, and this article will not attempt to cover all of them. A careful review of the code and consulting with your local building department are the only real ways to learn about what is required.

However, there are two major changes that will have the most potential to impact standard operating procedures for builders across the country:

- 1) Duct and general air leakage testing are now mandated for all homes where any portion of the HVAC system is not in conditioned space; and
- 2) A blower door test is required unless a new special air barrier and insulation inspection is performed.

In the 2006 energy code, duct tightness and blower door tests were optional under the performance path, but not required for either the performance or prescriptive paths. Now these tests, or a comparable visual inspection by a third party, are mandatory for any home with any part of the HVAC system not enclosed in conditioned space.

Many builders are unfamiliar with these types of tests and don't know where to start or whom to trust to complete them. To that end, we offer the following primer on duct tightness and blower door testing as they relate to the 2009 IECC.

## Duct tightness testing

Leaky ducts can be a significant source of energy loss in both new and existing homes. Leaky supply ducts can send expensive conditioned air into unconditioned spaces such as attics and crawl spaces, and can be responsible for inadequate air distribution, resulting in rooms that are too cold or too warm for occupant comfort. A measure of the air tightness of the duct system can help identify leaks, and simple duct sealing methods can save energy and increase occupant comfort.

The most common method of duct testing, a duct tightness test,

involves pressurizing the duct system with a calibrated fan. The supply registers are sealed off and the ductwork is pressurized (usually to 25 Pascals or 0.1 in. water column) with a fan located near the air handler. The rate of airflow (expressed in cubic feet per minute at 25 Pascals of pressure) into the ducts is used to determine the duct tightness. When used in conjunction with a blower door test, the duct air loss to the exterior of the house can be determined.

The 2009 IECC is silent on specifying who is authorized to conduct duct tightness testing. Typically, energy raters or analysts are skilled at conducting duct tests, as are many HVAC installers. If you are already working with an energy rater, you are likely performing this kind of testing on your homes. If you're not, you may want to work with your current HVAC contractor to see if they are willing to become qualified to conduct this type of performance testing.

The upfront cost for the necessary equipment to conduct duct tests is not too steep for any contractor looking to get into it, and you may benefit from time

and cost savings if your HVAC installer can wear both hats on your jobsite.

How and when is it done? For duct tightness testing, the 2009 energy code spells out three different phases of construction when the testing can be conducted, and four testing methods. Here's an overview of the acceptable methods and maximum readings based on the code:

- 1) **Rough-in test performed when only ducts are set.** The result should be a maximum of 4cfm/100 square feet of conditioned



A typical blower door test setup.

Photo courtesy Wayne-White Contracting Electrical Cooperative

area.

2) **Rough-in test after the air handler is installed.** The result should be a maximum of 6cfm/100 square feet of conditioned area.

3) **Post-construction testing of leakage to the outside of the building.** The result should be a maximum of 8cfm/100 square feet of conditioned area.

4) **Post-construction testing of total duct leakage.** The result should be a maximum of 12cfm/100 square feet of conditioned area.

To get the best test results possible, make sure to seal all take-offs, including flexible duct connections with tape, straps or mastic. It may also be beneficial to conduct the testing in one of the pre-close-in phases that are allowed - and easier and cheaper to go back and fix any leaks found before everything is sealed up behind the drywall.

If you haven't had duct testing conducted on your homes before, you may want to do a trial run on a home that was completed under the previous energy code just to see where your baseline is with your typical construction practices. That way you may be able to adjust your practices ahead of testing on the next home you build. It will be a lot easier than trying to find and repair duct leaks in the crawlspace or attic of a finished home.

The tightness requirement will be challenging for a number of HVAC installers who have never had their ducts tested. The other solution is to bring all ducts into conditioned space where a leaky duct does not directly result in wasting energy.

## Blower door testing

The blower door test measures the amount of air that flows into or out of a house while maintaining a set pressure difference between the indoors and outside. By using a calibrated fan and metering equipment, airflow can be measured at a variety of pressure differences around 50 Pascals. Test results are expressed in many ways, most commonly in air changes per hour, under natural conditions (ACHnat) or at test pressure (ACH50), airflow at test pressure (CFM50), or equivalent leakage area (usually square inches).

Tighter homes have lower values than leaky homes.

The blower door test is used to determine the airtightness of a home. A leaky house will lose more conditioned air to the outdoors or draw unconditioned air indoors. A very airtight house without mechanical ventilation can develop indoor air quality issues under some circumstances.

Who should perform the testing? Again, the code is not specific as to who can conduct blower door tests to be in compliance with the code. Home energy raters or analysts are

a good first choice for this kind of testing. However, the code also permits builders and insulation installers to conduct the tests; a third party is not required. You would obviously want to double check with your local code inspector to make sure he is comfortable with you conducting your own tests. If so, the initial investment in the equipment and training may be worth it to offset more costs for outside testers.

Blower door tests are always conducted after the home is completed. The maximum test result for a blower door test in all regions of the country is 7ACH at 50 Pascals.

As with duct tightness testing, it would be a good idea to perform a blower door test on a previously constructed home to gauge your baseline and identify what you might be able to do to improve your readings for a new home. Most homes with reasonable air sealing should be able to pass the 7ACH at 50 Pascals level.

## Visual inspection alternative

Where the 2009 energy code calls for building envelope tightness testing, there is an alternative available: third-party (or code official) visual inspections. Using this method, an HVAC or insulation installer would conduct a series of visual inspections to ensure that all ducts are properly sealed, insulation is installed properly, and cracks and openings to the outside are appropriately sealed. There are additional requirements for the visual inspection beyond those of typical air sealing, including insulated headers and corners, an air barrier behind tubs on an exterior wall, and air barriers in common walls separating dwelling units.

## Mastering party walls

One of the trickiest applications of the new code requirements for testing is residential buildings with party walls. There are many more variables for potential air leakage in these types of buildings than in single-family detached homes - including leakage between units, common areas and entrances, and variations in the number of exposed sides to each unit - and they are not all easily accounted for in the testing equation.

The 2009 IECC has a lot of ambiguity on this particular issue, and there is no true industry standard for duct tightness and blower door tests as they relate to multifamily and single-family attached buildings.

For these reasons, multifamily builders are probably best served to stick to the visual inspection option that is available under the new energy code, and make sure, in advance of any inspections, that local code officials are comfortable with that.

## Resources

There are many online resources to help you understand what steps are necessary to build a tighter house and install a tighter duct system, including the following:

### Duct Tightness Resources

- [www.greenbuildingadvisor.com/blogs/dept/musings/duct-leakage-testing](http://www.greenbuildingadvisor.com/blogs/dept/musings/duct-leakage-testing)
- [www.engr.psu.edu/phrc/training/Duct%20Leakage%20Testing.pdf](http://www.engr.psu.edu/phrc/training/Duct%20Leakage%20Testing.pdf)

### Building Tightness Resources

- [www.nrel.gov/docs/fy00osti/26446.pdf](http://www.nrel.gov/docs/fy00osti/26446.pdf)
- [www.habitat.org/env/pdf/air\\_sealing.pdf](http://www.habitat.org/env/pdf/air_sealing.pdf)

### Finding an Energy Rater

- [www.energytacgov/index.cfm?fuseaction=new\\_homes\\_partners\\_locator](http://www.energytacgov/index.cfm?fuseaction=new_homes_partners_locator)
- [www.natresnet.org/directory/raters.aspx](http://www.natresnet.org/directory/raters.aspx)
- [www.HousingZone.com/PB](http://www.HousingZone.com/PB)

## IECC 2009 Duct Tightness Verification

Pass / Fail

Date:

Permit No:

Street Address:

Total conditioned floor area:

HERS Rater:	
Certification Number:	
Signature:	
Builder:	
Building Contact:	
HVAC Contractor:	

### Postconstruction Test

- ☐ Total Leakage – 12 cfm/100 ft<sup>2</sup> maximum allowed
- ☐ Leakage to outdoors – 8 cfm/100 ft<sup>2</sup> maximum allowed

Testing result: \_\_\_\_\_ cfm/100 ft<sup>2</sup>

### Rough-in Test

#### Total Leakage

Air Handler Installed?

- ☐ Yes – 6 cfm/100 ft<sup>2</sup> maximum allowed
- ☐ No – 4 cfm/100 ft<sup>2</sup> maximum allowed

Testing result: \_\_\_\_\_ cfm/100 ft<sup>2</sup>

2. Site-built windows, doors and skylights.
3. Openings between window and door assemblies and their respective jambs and framing.
4. Utility penetrations.
5. Dropped ceilings or chases adjacent to the thermal envelope.
6. Knee walls.
7. Walls and ceilings separating a garage from conditioned spaces.
8. Behind tubs and showers on exterior walls.
9. Common walls between dwelling units.
10. Attic access openings.
11. Rim joist junction.
12. Other sources of infiltration.

**402.4.2 Air sealing and insulation.** Building envelope air tightness and insulation installation shall be demonstrated to comply with one of the following options given by Section 402.4.2.1 or 402.4.2.2:

**402.4.2.1 Testing option.** Building envelope tightness and insulation installation shall be considered acceptable when tested air leakage is less than seven air changes per hour (ACH) when tested with a blower door at a pressure of 50 pascals (1 psf). Testing shall occur after rough in and after installation of penetrations of the building envelope, including penetrations for utilities, plumbing, electrical, ventilation and combustion appliances.

During testing:

1. Exterior windows and doors, fireplace and stove doors shall be closed, but not sealed;
2. Dampers shall be closed, but not sealed, including exhaust, intake, makeup air, backdraft and flue dampers;
3. Interior doors shall be open;
4. Exterior openings for continuous ventilation systems and heat recovery ventilators shall be closed and sealed;
5. Heating and cooling system(s) shall be turned off;
6. HVAC ducts shall not be sealed; and
7. Supply and return registers shall not be sealed.

**402.4.2.2 Visual inspection option.** Building envelope tightness and insulation installation shall be considered acceptable when the items listed in Table 402.4.2, applicable to the method of construction, are field verified. Where required by the *code official*, an *approved* party independent from the installer of the insulation shall inspect the air barrier and insulation.

**402.4.3 Fireplaces.** New wood-burning fireplaces shall have gasketed doors and outdoor combustion air.

**402.4.4 Fenestration air leakage.** Windows, skylights and sliding glass doors shall have an air infiltration rate of no

more than 0.3 cfm per square foot (1.5 L/s/m<sup>2</sup>), and swinging doors no more than 0.5 cfm per square foot (2.6 L/s/m<sup>2</sup>), when tested according to NFRC 400 or AAMA/WDMA/CSA 101/I.S.2/A440 by an accredited, independent laboratory and *listed* and *labeled* by the manufacturer.

**Exceptions:** Site-built windows, skylights and doors.

**402.4.5 Recessed lighting.** Recessed luminaires installed in the *building thermal envelope* shall be sealed to limit air leakage between conditioned and unconditioned spaces. All recessed luminaires shall be IC-rated and *labeled* as meeting ASTM E 283 when tested at 1.57 psf (75 Pa) pressure differential with no more than 2.0 cfm (0.944 L/s) of air movement from the *conditioned space* to the ceiling cavity. All recessed luminaires shall be sealed with a gasket or caulk between the housing and the interior wall or ceiling covering.

**402.5 Maximum fenestration U-factor and SHGC (Mandatory).** The area-weighted average maximum fenestration U-factor permitted using trade-offs from Section 402.1.4 or 405 shall be 0.48 in Zones 4 and 5 and 0.40 in Zones 6 through 8 for vertical fenestration, and 0.75 in Zones 4 through 8 for skylights. The area-weighted average maximum fenestration SHGC permitted using trade-offs from Section 405 in Zones 1 through 3 shall be 0.50.

## SECTION 403 SYSTEMS

**403.1 Controls (Mandatory).** At least one thermostat shall be provided for each separate heating and cooling system.

**403.1.1 Programmable thermostat.** Where the primary heating system is a forced-air furnace, at least one thermostat per dwelling unit shall be capable of controlling the heating and cooling system on a daily schedule to maintain different temperature set points at different times of the day. This thermostat shall include the capability to set back or temporarily operate the system to maintain zone temperatures down to 55°F (13°C) or up to 85°F (29°C). The thermostat shall initially be programmed with a heating temperature set point no higher than 70°F (21°C) and a cooling temperature set point no lower than 78°F (26°C).

**403.1.2 Heat pump supplementary heat (Mandatory).** Heat pumps having supplementary electric-resistance heat shall have controls that, except during defrost, prevent supplemental heat operation when the heat pump compressor can meet the heating load.

### 403.2 Ducts.

**403.2.1 Insulation (Prescriptive).** Supply ducts in attics shall be insulated to a minimum of R-8. All other ducts shall be insulated to a minimum of R-6.

**Exception:** Ducts or portions thereof located completely inside the *building thermal envelope*.

**403.2.2 Sealing (Mandatory).** All ducts, air handlers, filter boxes and building cavities used as ducts shall be sealed.

Joints and seams shall comply with Section M1601.4.1 of the *International Residential Code*.

Duct tightness shall be verified by either of the following:

1. Postconstruction test: Leakage to outdoors shall be less than or equal to 8 cfm (226.5 L/min) per 100 ft<sup>2</sup> (9.29 m<sup>2</sup>) of *conditioned floor area* or a total leakage less than or equal to 12 cfm (12 L/min) per 100 ft<sup>2</sup> (9.29 m<sup>2</sup>) of *conditioned floor area* when tested at a pressure differential of 0.1 inches w.g. (25 Pa) across the entire system, including the manufacturer's air handler enclosure. All register boots shall be taped or otherwise sealed during the test.

2. Rough-in test: Total leakage shall be less than or equal to 6 cfm (169.9 L/min) per 100 ft<sup>2</sup> (9.29 m<sup>2</sup>) of *conditioned floor area* when tested at a pressure differential of 0.1 inches w.g. (25 Pa) across the roughed in system, including the manufacturer's air handler enclosure. All register boots shall be taped or otherwise sealed during the test. If the air handler is not installed at the time of the test, total leakage shall be less than or equal to 4 cfm (113.3 L/min) per 100 ft<sup>2</sup> (9.29 m<sup>2</sup>) of *conditioned floor area*.

**Exceptions:** Duct tightness test is not required if the air handler and all ducts are located within *conditioned space*.

TABLE 402.4.2  
AIR BARRIER AND INSULATION INSPECTION COMPONENT CRITERIA

COMPONENT	CRITERIA
Air barrier and thermal barrier	Exterior thermal envelope insulation for framed walls is installed in substantial contact and continuous alignment with building envelope air barrier. Breaks or joints in the air barrier are filled or repaired. Air-permeable insulation is not used as a sealing material. Air-permeable insulation is inside of an air barrier.
Ceiling/attic	Air barrier in any dropped ceiling/soffit is substantially aligned with insulation and any gaps are sealed. Attic access (except unvented attic), knee wall door, or drop down stair is sealed.
Walls	Corners and headers are insulated. Junction of foundation and sill plate is sealed.
Windows and doors	Space between window/door jambs and framing is sealed.
Rim joists	Rim joists are insulated and include an air barrier.
Floors (including above-garage and cantilevered floors)	Insulation is installed to maintain permanent contact with underside of subfloor decking. Air barrier is installed at any exposed edge of insulation.
Crawl space walls	Insulation is permanently attached to walls. Exposed earth in unvented crawl spaces is covered with Class I vapor retarder with overlapping joints taped.
Shafts, penetrations	Duct shafts, utility penetrations, knee walls and flue shafts opening to exterior or unconditioned space are sealed.
Narrow cavities	Batts in narrow cavities are cut to fit, or narrow cavities are filled by sprayed/blown insulation.
Garage separation	Air sealing is provided between the garage and conditioned spaces.
Recessed lighting	Recessed light fixtures are air tight, IC rated, and sealed to drywall. Exception—fixtures in conditioned space.
Plumbing and wiring	Insulation is placed between outside and pipes. Batt insulation is cut to fit around wiring and plumbing, or sprayed/blown insulation extends behind piping and wiring.
Shower/tub on exterior wall	Showers and tubs on exterior walls have insulation and an air barrier separating them from the exterior wall.
Electrical/phone box on exterior walls	Air barrier extends behind boxes or air sealed-type boxes are installed.
Common wall	Air barrier is installed in common wall between dwelling units.
HVAC register boots	HVAC register boots that penetrate building envelope are sealed to subfloor or drywall.
Fireplace	Fireplace walls include an air barrier.



## ENERGY STAR Qualified Homes Thermal Bypass Inspection Checklist

The Thermal Bypass Inspection Checklist must be completed for homes to earn the ENERGY STAR label. The Checklist requires visual inspection of framing areas where air barriers are commonly missed and inspection of insulation to ensure proper alignment with air barriers, thus serving as an extra check that the air and thermal barriers are continuous and complete. State, local, and regional codes, as well as regional ENERGY STAR program requirements, supersede the items specified in this Checklist.

### Guidance on Completing the Thermal Bypass Inspection Checklist:

1. Accredited HERS Providers and certified home energy raters shall use their experience and discretion in verifying that each Inspection Checklist item is installed per the inspection guidelines (e.g., identifying minor defects that the Provider or rater deems acceptable versus identifying major defects that undermine the intent of the Checklist item).
2. Alternative methods of meeting the Checklist requirements may be used in completing the Checklist, if the Provider deems them to be equivalent, or more stringent, than the Inspection Checklist guidelines.
3. In the event an item on the Checklist cannot be verified by the rater, the home cannot be qualified as ENERGY STAR, unless the builder assumes responsibility for verifying that the item has met the requirements of the Checklist. This option is available at the discretion of the Provider or rater but may not be used to verify more than six (6) items on the Inspection Checklist. This responsibility will be formally acknowledged by the builder signing-off on the Checklist for the item(s) that they verified. The column titled "N/A" should be used when the checklist item is not present in the home or when local code requirements take precedent.
4. The Checklist may be completed for a batch of homes using a RESNET-approved sampling protocol when qualifying homes as ENERGY STAR. For example, if the approved sampling protocol requires rating one in seven homes, then the Checklist will be completed for the one home which was rated.
5. In the event that a Provider or rater finds an item that is inconsistent with the Checklist Inspection guidelines, the home cannot be qualified as ENERGY STAR until the item is corrected in a manner that meets the ENERGY STAR requirements. If correction of the item is not possible, the home cannot earn the ENERGY STAR label.
6. The Provider or rater is required to keep a hard copy record of the completed and signed Checklist. The signature of a builder employee is also required if the builder verified compliance with any item on the Checklist.
7. For purposes of this Checklist, an air barrier is defined as any solid material that blocks air flow between a conditioned space and an unconditioned space, including necessary sealing to block excessive air flow at edges and seams. Additional information on proper air sealing of thermal bypasses can be found on the Building America Web site ([www.eere.energy.gov/buildings/building\\_america](http://www.eere.energy.gov/buildings/building_america)) and in the EEBA Builder's Guides ([www.eeba.org](http://www.eeba.org)). These references include guidance on identifying and sealing air barriers, as well as details on many of the items included in the Checklist.



# ENERGY STAR Qualified Homes Thermal Bypass Inspection Checklist

Home Address: _____		City: _____		State: _____	
Thermal Bypass	Inspection Guidelines	Corrections Needed	Builder Verified	Rater Verified	N/A
1. Overall Air Barrier and Thermal Barrier Alignment	<b>Requirements:</b> Insulation shall be installed in full contact with sealed interior and exterior air barrier except for alternate to interior air barrier under item no. 2 ( <i>Walls Adjoining Exterior Walls or Unconditioned Spaces</i> ) <b>All Climate Zones:</b> 1.1 Overall Alignment Throughout Home 1.2 Garage Band Joist Air Barrier (at bays adjoining conditioned space) 1.3 Attic Eave Baffles Where Vents/Leakage Exist <b>Only at Climate Zones 4 and Higher:</b> 1.4 Slab-edge Insulation (A maximum of 25% of the slab edge may be uninsulated in Climate Zones 4 and 5) <b>Best Practices Encouraged, Not Req'd.:</b> 1.5 Air Barrier At All Band Joists (Climate Zones 4 and higher) 1.6 Minimize Thermal Bridging (e.g., OVE framing, SIPs, ICFs)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. Walls Adjoining Exterior Walls or Unconditioned Spaces	<b>Requirements:</b> • Fully insulated wall aligned with air barrier at both interior and exterior, <b>OR</b> • Alternate for <b>Climate Zones 1 thru 3</b> , sealed exterior air barrier aligned with RESNET Grade 1 insulation fully supported • Continuous top and bottom plates or sealed blocking 2.1 Wall Behind Shower/Tub 2.2 Wall Behind Fireplace 2.3 Insulated Attic Slopes/Walls 2.4 Attic Knee Walls 2.5 Skylight Shaft Walls 2.6 Wall Adjoining Porch Roof 2.7 Staircase Walls 2.8 Double Walls	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3. Floors between Conditioned and Exterior Spaces	<b>Requirements:</b> • Air barrier is installed at any exposed fibrous insulation edges • Insulation is installed to maintain permanent contact with sub-floor above including necessary supports (e.g., staves for blankets, netting for blown-in) • Blanket insulation is verified to have no gaps, voids or compression. • Blown-in insulation is verified to have proper density with firm packing 3.1 Insulated Floor Above Garage 3.2 Cantilevered Floor	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4. Shafts	<b>Requirements:</b> Openings to unconditioned space are fully sealed with solid blocking or flashing and any remaining gaps are sealed with caulk or foam (provide fire-rated collars and caulking where required) 4.1 Duct Shaft 4.2 Piping Shaft/Penetrations 4.3 Flue Shaft	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5. Attic/ Ceiling Interface	<b>Requirements:</b> • All attic penetrations and dropped ceilings include a full interior air barrier aligned with insulation with any gaps fully sealed with caulk, foam or tape • Movable insulation fits snugly in opening and air barrier is fully gasketed 5.1 Attic Access Panel (fully gasketed and insulated) 5.2 Attic Drop-down Stair (fully gasketed and insulated) 5.3 Dropped Ceiling/Soffit (full air barrier aligned with insulation) 5.4 Recessed Lighting Fixtures (ICAT labeled and sealed to drywall) 5.5 Whole-house Fan (Insulated cover gasketed to the opening)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6. Common Walls Between Dwelling Units	<b>Requirements:</b> Gap between drywall shaft wall (i.e., common wall) and the structural framing between units is fully sealed at all exterior boundary conditions 6.1 Common Wall Between Dwelling Units	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Home Energy Rating Provider: _____ Rater Inspection Date: _____ Builder Inspection Date: _____					
Home Energy Rater Company Name: _____ Builder Company Name: _____					
Home Energy Rater Signature: _____ Builder Employee Signature: _____					